

## **MOTORCYCLE LATERAL SUSPENSION MECHANISM**

### **CROSS-REFERENCE TO RELATED APPLICATIONS, IF ANY**

Not applicable.

### **STATEMENT REGARDING FEDERALLY SPONSORED 5 RESEARCH OR DEVELOPMENT**

Not applicable.

### **REFERENCE TO A MICROFICHE APPENDIX, IF ANY**

Not applicable.

## **BACKGROUND OF THE INVENTION**

### **10 1. Field of the Invention.**

The present invention is a device for providing deployable, adjustable, controlled flex and lateral suspension movement to a motorcycle chassis.

### **2. Background information.**

This invention is a device for providing deployable, adjustable, controlled flex and lateral suspension movement to a motorcycle chassis for the purpose of enhancing handling characteristics when leaned-over, and at slower speeds, but without compromising stability when the motorcycle is upright, and at high speeds.

Over the last twenty years or so, advances in motorcycle chassis and tire design have delivered great improvements in handling characteristics, especially with respect to high-speed stability. Unlike 20 earlier chassis designs, which were often flexible to the point that dangerous instability would surface at any elevated speed, modern performance oriented motorcycles remain generally stable in most situations. While motorcycling has clearly benefitted from these advancements in frame, suspension, and tire technology, one area that arguably needs more attention is that of leaned-over traction and

rider "feel." Many earlier flex-prone designs, while often frightening at elevated speeds and when mostly upright, generally remained more-or-less stable and offered good "feel" and compliance to surface irregularities when leaned-over, as when cornering. While the older "flexible" chassis absorbed some of the energy of a bump, the newer "rigid" chassis cannot. The modern chassis are rigid to the

5 point that when leaned-over, irregularities in the road surface sometimes deflect the tires in an arc about the center of mass of the machine, resulting in a loss of traction. One might expect the suspension to absorb this bump energy, but this is not always possible. Looking at the forces acting on the motorcycle offers insight as to why very rigid chassis don't always perform as well as they might. As illustrated in drawing FIGS. 1 and 2, the bump force which acts on the suspension when

10 leaned-over, as when cornering, is a portion of that which acts on the suspension when the motorcycle is upright. Additionally, centrifugal force tends to pre-load the suspension when cornering, making the suspension effectively stiffer. Some increase in friction in the telescopic front fork may also be present when cornering, as it is loaded at an angle to its normal plane of operation.

In essence, when cornering, a lesser force is available to act on suspension that is less likely to be

15 moved by that force. Because of this, in some cases, when an irregularity in the road surface is encountered, the tires may leave the road surface or be unloaded to the point that they lose traction. This can result in chatter, instability, or even momentary "high-side" crash inducing losses of traction.

Since the suspension must accommodate braking dive forces, stability, comfort, and cornering

20 clearance constraints, softer springs and modified damping are not a viable option to deal with this lessened force. A fully active suspension system may be an answer to this problem, but complexity and power requirements make it impractical at present. It is apparent that some chassis flex or lateral suspension movement can be beneficial to handling in some situations, and detrimental in others.

Applicant has invented a lateral suspension device, which provides deployable, adjustable, controlled flex and lateral suspension movement to a motorcycle chassis. The amount of deflection and the force required to initiate the deflection is adjustable. The device may be deployed as desired per rider preference and conditions. In two embodiments, the device is actuated automatically per 5 inputs to a programmable logic unit. A third embodiment is manually adjusted.

## **SUMMARY OF THE INVENTION**

The invention is a device for providing deployable, adjustable, controlled flex and lateral suspension movement to a motorcycle chassis. The device consists of a swingarm pivot mechanism, which is capable of providing multiple levels of lateral deflection to the swingarm member. Generally, 10 the device is fully activated when the motorcycle is fully leaned-over and at lower speeds and inactivated when the motorcycle is upright and traveling at very high speeds. Preferably, the device is partially activated dependent on the speed, lean angle, and other factors. Acting on inputs such as lean angle, speed, transmission gear position, engine speed, throttle position, brake application, suspension position, and a rider override switch, a programmable logic unit controls either a hydraulic cylinder actuator or an electric screw actuator to operate a rotary cam. The cam, when rotated, provides a selected amount of axial slack in the swingarm pivot axle. When slack is present, the swingarm pivot axle is free to move axially and the swingarm member is free to move laterally to a selected degree. The swingarm member's lateral movement is controlled by flexure members, which 15 dictate the force needed for movement. The flexure members are held in place against the pivot ends of the swingarm member by threaded fasteners, which allow for adjustment, as well as allowing for some preloading if desired. The flex characteristics of the flexure members is varied by construction 20

of the flexure members from selected materials, by changing their shape, by adding features, such as apertures, or by construction featuring multiple layers of similar or dissimilar materials. In a first embodiment, the invention is applied to a chassis in which the swingarm member pivots between outboard frame members, and the outboard frame members locate the flexure member mounts.

5           In a second embodiment, the invention is applied to a chassis in which the swingarm member pivots between outboard frame members and an engine case or a central frame member. In this embodiment, the flexure member mounts may be located in the outboard frame members or on the engine case or central frame member.

10          In a third embodiment of the invention, the device functions without an actuator and is manually adjusted per rider preference and conditions. This embodiment may be applied to chassis, which use outboard frame members to mount the swingarm member pivot or those that use outboard frame members and an engine case or a central frame member to mount the swingarm member pivot.

15          In the broadest concept, the mechanism includes a swingarm pivot axle rotatably securing the swingarm member to the frame. A pair of flexure members, each are secured to the frame by a plurality of flexure member mounts, and each include an aperture accepting the swingarm pivot axle. Also present is a means for adjustably controlling the degree of lateral axial deflection of the swingarm pivot axle and associated swingarm member relative to the frame and attached flexure members during operation of the motorcycle.

20          In one embodiment, the adjustable controlling means includes a cam assembly encircling the swingarm pivot axle. The cam assembly comprising a cam stationary member rigidly secured to the frame and a cam rotating member rotatable by an actuator, the cam members including at least one ramped contact surface there between. An actuator rotates the cam rotating member to provide a

variable degree of lateral, axial deflection of the swingarm pivot axle relative to the frame, and each flexure member is positioned to control axial deflection of the swingarm member in one of two opposed directions relative to the frame and attached flexure members during operation of the motorcycle.

5 In another embodiment, the adjustable controlling means includes a swingarm locking nut member secured to a threaded end of the swingarm pivot axle and securing the swingarm member to the frame. The nut member is adjustable to provide a single, selected degree of lateral, axial deflection of the swingarm pivot axle relative to the frame, and each flexure member is positioned to control lateral, axial deflection of the swingarm member in one of two opposed directions relative to the 10 frame and attached flexure members during operation of the motorcycle.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a front view of a motorcycle chassis encountering a surface irregularity while in an upright position.

15 FIG. 2 is a front view of a motorcycle chassis encountering a surface irregularity while in a leaned-over position. An expression of the force available to act on the suspension is included.

FIG. 3 is a side view of a motorcycle chassis opposite the actuator side of the invention, in a first embodiment of the invention.

FIG. 4 is an enlarged detail side view of a portion of FIG. 3 opposite the actuator side of the invention, in a first embodiment of the invention.

20 FIG. 5 is a side view of a motorcycle chassis on the actuator side of a first embodiment of the invention, in which the actuator is a hydraulic cylinder.

FIG. 6 is an enlarged detail view of a portion of FIG. 5 on the actuator side of a first embodiment of the invention, in which the actuator is a hydraulic cylinder.

FIG. 7 is a side view of a motorcycle chassis on the actuator side of a first embodiment of the invention, with an electric screw actuator.

5 FIG. 8 is an enlarged detail view of a portion of FIG. 7 on the actuator side of a first embodiment of the invention, with an electric screw actuator.

FIG. 9 is a section view along line 9-9 of FIG. 6 of a first embodiment of the invention.

FIG. 10 is an enlarged detail view of a portion of FIG. 9 opposite the actuator end of the invention.

10 FIG. 11 is an enlarged detail view of another portion of FIG. 9 showing the actuator end of the invention.

FIG. 12 is an end view from line 12-12 of FIG. 6 of a first embodiment of the invention in an unoperated state. Note that the dimension "X" is essentially zero.

15 FIG. 13 is an end view from line 13-13 of FIG 6 of a first embodiment of the invention in an operated state. Note that the dimension "X" is a selected distance dependent upon the amount of cam rotation.

FIG. 14 is a side view of a motorcycle chassis showing a second embodiment of the invention.

FIG. 15 is an enlarged detail side view of a portion of FIG. 14 showing a second embodiment of the invention.

20 FIG. 16 is a section view along line 16-16 of FIG. 15 of a motorcycle chassis showing a second embodiment of the invention. In this embodiment, in addition to outboard frame members, an engine case or central frame member is used to support the swingarm pivot axle. The engine case or central frame member also locates the flexure member mounts.

FIG. 17 is an end view from line 17-17 of FIG. 15 of a second embodiment of the invention in an unoperated state. Note that the dimension "X" is essentially zero, and that the dimension increases a selected distance upon rotation of the cam a selected amount.

FIG. 18 is a side view of a motorcycle chassis showing a third embodiment of the invention.

5 FIG. 19 is an enlarged detail side view of a portion of FIG. 18 showing a third embodiment of the invention.

FIG. 20 is an end view from line 20-20 of FIG. 19 of a third embodiment of the invention. Note that the dimension "X" increases as the self-locking nut is loosened.

FIG. 21 is a side view of a flexure member.

10 FIG. 22 is a side view of another flexure member illustrating variation in the shape of the flexure member to vary its flex characteristics.

FIG. 23 is a side view of another flexure member illustrating how features, in this case apertures, are added to vary the flex characteristics of the member.

15 FIG. 24 is an end view of another flexure member illustrating how the member is composed of multiple layers of various materials to vary the flex characteristics of the flexure member.

FIG. 25 is a schematic representation of the actuator control system of an embodiment of the invention with hydraulic actuation.

FIG. 26 is a schematic representation of the actuator control system of an embodiment of the invention with screw actuation.

## DESCRIPTION OF THE EMBODIMENTS

### *Nomenclature*

1	Frame
2	Front Fork
5	3 Front Wheel
4	Swingarm Member
5	Rear Wheel
6	Swingarm Pivot Axle
7	Swingarm Axle Self-locking Nut
10	8 Bushing
9	Needle Bearing
10	10 Collar
11	11 Thrust Bearing
12	12 Engine Case or Central Frame Member
15	13 End Cap and Seal
14	14 Cam Stationary Member
15	15 Cam Fixing Pin
16	16 Cam Rotating Member
17	17 Cam Arm
20	18 Spring
19	19 Spring Mounting Pin
20	20 Cam Arm Joint

- 21 Cam Thrust Bearing
- 22 Thrust Collar
- 23 Flexure Member
- 24 Threaded Flexure Member Mount
- 5 25 Locknut
- 26 Locknut
- 27 Hydraulic Cylinder Actuator
- 28 Electric Screw Actuator
- 29 Actuator Mount
- 10 30 Washer
- 31 Shoulder
- 32 Bushing
- 33 Oil Pump
- 34 Battery or Power Source
- 15 35 Valve
- 36 Accumulator
- 37 Mechanism Cam Angle Sensor
- 38 Lean Angle Sensor
- 39 Vehicle Speed Sensor
- 20 40 Transmission Gear Position Sensor
- 41 Engine Speed Sensor
- 42 Throttle Position Sensor

- 43      Brake Actuation Sensor
- 44      Suspension Position Sensor
- 45      Rider Override Switch
- 46      Logic Unit
- 5        47      Reservoir
- 48      Filter
- 49      One-way Valve
- 50      Unloading Valve
- 51      Suspension Shock

## 10      ***Construction***

Although the disclosure hereof is detailed and exact to enable those skilled in the art to practice the invention, the physical embodiments herein disclosed merely exemplify the invention, which may be embodied in other specific structure. The scope of the invention is defined in the claims appended hereto.

15      Referring to FIGS. 3, 5, 7, 14 and 18, the basic structural components of a motorcycle incorporating various embodiments of the invention are illustrated. The structural components include a frame 1 with a front wheel mounted in a front fork 2 secured at one end of the frame 1, and a swingarm member 4 pivotally secured at the opposite end of the frame 1. A rear wheel 5 is mounted to the swingarm member 4 opposite the pivot point thereof. A suspension shock 51 is mounted between the frame and the swingarm member 4 to limit vertical pivoting of the swingarm member 4 and provide a degree of vertical flex to the chassis. The additional components of the

motorcycle, such as the motor, transmission and/or drive train, the fuel tank and rider seat are omitted from these five figures for clarity.

The invention is a mechanism that is added to or built into the swingarm pivot of a motorcycle chassis. In a first embodiment of the invention, shown in FIGS. 3 through 13, a swingarm pivot axle 6 is fitted into bushings 8 which are pressed into apertures in the motorcycle frame 1. A concentric shoulder 31 on one end of the swingarm pivot axle 6 provides a close slideable fit into one of the bushings 8. If the motorcycle frame 1 is of suitable construction and material, the swingarm pivot axle 6, optionally, is fitted into apertures in the motorcycle frame 1 without bushings 8. The shoulder 31 end of the swingarm pivot axle 6 includes a hex head, or other feature, to retain the axle 6 to the frame 1, while a self-locking nut 7 is tightened on the opposite end of the axle 6, which is threaded. When installed into the bushings 8, the hex head of the axle 6 is on one outboard side of the frame 1 and the threaded end and self-locking nut 7 is on the other outboard side of the frame 1. On the inboard sides of the frame 1, the swingarm pivot axle 6 passes through flexure members 23, one on each side, and end cap and seals 13, one on each side, which captures the swingarm member 4, best illustrated in FIG.9.

A cam stationary member 14 is slideably fitted to the axle 6 and captured directly behind the self-locking nut 7. The cam stationary member 14 is prevented from rotating by a cam fixing pin 15, which is fixed to the motorcycle frame 1 and extends through an aperture, or other such feature, in the cam stationary member 14. The cam stationary member 14 is acted on by a cam rotating member 16, which is fitted rotatably and slideably to the axle 6 and is registered to the cam stationary member 14. The cam members 14, 16 include at least one ramped contact surface there between. The cam rotating member 16 acts on a cam thrust bearing 21, which in turn, acts on a thrust collar 22. The

thrust collar 22 is fitted slideably to the axle 6 and slideably through a bushing 8. A hydraulic cylinder 27 (FIGS. 5 and 6), or an electric screw actuator 28 (FIGS. 7 and 8), is fixed to the motorcycle frame 1 by an actuator mount 29, which comprises a bolt, stud or other such device. The hydraulic cylinder 27, or electric screw actuator 28, is connected pivotally to the cam arm 17 of the cam rotating member 16 by a cam arm joint 20. In the embodiment employing a hydraulic cylinder 27, a spring 18 is preferably fitted between the frame 1 and cam arm 17 by spring mounting pins 19 fixed to the frame 1 and the cam arm 17 (FIG. 6). The spring 18 maintains pressure against the piston seals of the hydraulic cylinder 27. The spring 18 provides a biasing force that tends to return the mechanism to an unoperated state, should there be a loss of fluid or pressure.

A plurality of threaded flexure member mounts 24 are threaded into an array of threaded apertures in both sides of the frame 1 surrounding the swingarm pivot bushings 8. The threaded flexure member mounts 24 feature a stepped end to present a shoulder on which the flexure members 23 mount. The threaded flexure member mounts 24 have internal hex features, or other such features, so that the mounts 24 may be turned to adjust the placement of the flexure members 23 in relation to the end caps and seals 13 fitted to the swingarm member 4. A locknut 25 prevents each threaded flexure member mount 24 from turning in the threaded apertures in the frame 1. Locknuts 26 fasten the flexure members 23 to the threaded flexure member mounts 24. The flexure members 23 are positioned concentrically to the swingarm pivot axle 6 by the threaded flexure member mounts 24. The flexure members 23 each feature a central aperture which is nominally larger than the diameter of the shoulder 31 of the swingarm pivot axle 6, and the outside diameter of the thrust collar 22.

As shown in FIGS. 9, 10, and 11, the swingarm member 4 features needle bearings 9 which are pressed into the swingarm member 4. The needle bearings 9 ride on a collar 10, which fits slideably

to the swingarm pivot axle **6**. Thrust bearings **11** are fitted to the pivot ends of the swingarm member **4**. An end cap and seal **13** is fitted rotatably over each pivot end of the swingarm member **4**. A concentrically located aperture in each end cap and seal **13** is nominally larger than the diameter of the axle **6**, which passes through the aperture in each end cap and seal **13**.

5 In a second embodiment of the invention, shown in FIGS. 14 through 17, an engine case or central frame member **12** is used for additional support to the swingarm member **4** pivot. The swingarm member **4** bearing area is separated so that it straddles the engine case or central frame member **12**. Each side of the swingarm member **4** includes a needle bearing **9**, a collar **10**, two trust bearings **11**, and two end caps and seals **13**. The swingarm pivot axle **6** passes through bushings **8** in 10 the frame **1** and through a bushing **32** in the engine case or central frame member **12**. A plurality of threaded flexure member mounts **24** are threaded into an array of threaded apertures in both sides of the engine case or central frame member **12**, as shown in FIG. 16. Flexure members **23** are fastened to the threaded flexure member mounts **24** by locknuts **26** to each side of the case or frame member **12**. The threaded flexure member mounts **24** have internal hex features, or other such features, 15 allowing the mounts **24** to be turned to adjust the placement of the flexure members **23** in relation to the end caps and seals **13** fitted to the swingarm member **4**. In this embodiment, the two outboard end caps and seals **13** are acted on by the shoulder **31** of the swingarm pivot axle **6** and by the thrust collar **22**. The two inboard end caps and seals **13** are acted on by the flexure members **23**.

20 In the first and second embodiments described above, the mechanism functions as follows: In an unoperated state, no axial play is present in the swingarm member **4** pivot. The pivot axle **6** is held immovably to the frame **1**, as illustrated in FIGS. 12 and 17. The swingarm member **4** is held laterally immobile by the shoulder **31** of the swingarm pivot axle **6** on one side, and by the thrust collar **22** on

the other side acting on its end caps and seals 13. In this state, the swingarm member 4 can rotate about the swingarm pivot axle 6, but cannot move laterally. When the mechanism is activated, the hydraulic cylinder 27, or electric screw actuator 28, acts on the cam arm 17 to rotate the cam rotating member 16. The cam members 14, 16 include at least one ramped contact surface there between. As 5 the cam rotating member 16 rotates against the cam stationary member 14, the distance between the outside faces of the cam members 14 and 16 decreases. The decrease in distance between the cam members 14 and 16 is the amount of axial play that is introduced into the mechanism, and the swingarm member 4 is free to move axially a corresponding distance. The above described control is illustrated in FIGS. 12, 13, and 17. When axial play is present, the swingarm member 4 is held laterally 10 by the flexure members 23 acting on the end caps and seals 13, which in turn, act on the thrust bearings 11. The flexure members 23 then allow the swingarm member 4 to move laterally if a sufficient lateral force acts on the swingarm member 4. Flex characteristics are adjusted by preloading the flexure members 23, by adjusting the threaded flexure member mounts 24, or by replacing or modifying the flexure members 23. FIGS. 21, 22, 23, and 24 illustrate how the flex characteristics 15 of the flexure members 23 are varied by changing the shape of the flexure members 23, by adding features, such as apertures, or by construction of the flexure members 23 with multiple layers of various materials. The orientation, spacing, and number of threaded flexure member mounts 24 also can be employed to vary the in-place flex characteristics of the flexure members 23.

Further in the first and second embodiments of the invention, the mechanism is controlled by 20 a logic unit 46 (FIGS. 25 and 26) acting on inputs from one or more of the following; a mechanism cam angle sensor 37, a lean angle sensor 38, a vehicle speed sensor 39, a transmission gear position sensor 40, an engine speed sensor 41, a throttle position sensor 42, a brake actuation sensor 43, a

suspension position sensor **44**, and a rider override switch **45**.

When employing actuation by a hydraulic cylinder **27**, as schematically illustrated in FIG. 25, oil, or other suitable media, is pumped from a reservoir **47**, through a filter **48**, by an oil pump **33**, and moves to an accumulator **36**, which maintains an appropriate pressure to operate the hydraulic cylinder

5      **27**. One-way valves **49** prevent back-flow, and an unloading valve **50** conserves power as it shunts oil from the oil pump **33** to the reservoir **47** once sufficient pressure is attained in the accumulator **36**. The logic unit **46**, acting on inputs described above, controls a valve **35**, which sends oil from the accumulator **36** to the appropriate port of the hydraulic cylinder **27** to operate the cam mechanism. The oil exhausted by the hydraulic cylinder **27** returns to the oil reservoir **47**. The hydraulics may be 10      an independent system, or may be part of the motorcycle engine lubrication system.

When employing actuation by an electric screw actuator **28**, schematically illustrated in FIG. 26, the logic unit **46**, acting on one or more inputs as described above, sends power from a battery and/or another electric power source **34** to the appropriate lead of the electric screw actuator **28** to operate the cam mechanism.

15      In either the case of the hydraulic cylinder actuator **27**, or the electric screw actuator **28**, the mechanism cam angle sensor **37** provides feedback to the logic unit **46** to verify the position of the cam rotating member **16**. The amount of rotation of the cam rotating member **16**, and corresponding lateral swingarm member **4** movement, may continuously be varied, per inputs described above, by programming in the logic unit **46**. Alternatively, adjustable limit switches (not shown) can be used 20      to set limits for rotation of the cam rotating member **16**.

In a third embodiment of the invention, shown in FIGS. 18, 19, and 20, the mechanism

functions without an actuator and is manually adjusted per conditions and rider preference. The stationary and rotating cam members **14** and **16**, and the cam thrust bearing **21**, are not present in this embodiment. The internal features of the swingarm member pivot **4** are as shown in FIG. 9. A shortened swingarm pivot axle **6**, and a washer **30** are put in place. The swingarm axle self-locking nut **7** functions to manually set the desired amount of axial play in the mechanism. Flex characteristics are adjusted by preloading the flexure members **23** by adjusting the threaded flexure member mounts **24**, or by replacing or modifying the flexure members. FIGS. 21, 22, 23, and 24 illustrate how the flex characteristics of the flexure members **23** are varied by changing the shape of the flexure members **23**, by adding features, such as apertures, or by construction of the flexure members **23** with multiple layers of various materials. The orientation, spacing, and number of threaded flexure member mounts **24** also are used to vary the in-place flex characteristics of the flexure members **23**. The third embodiment is applicable to a chassis which uses only outboard frame **1** members to locate the swingarm pivot axle **6** and to chassis which use outboard frame **1** members and an engine case or central frame member **12** to locate the swingarm pivot axle **6**.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.